Pan American Development Foundation/PLUS Project
27, Delmas 31, Port-au-Prince, Haïti
Adresse Postale: B. P. 15574, Pétionville, Haïti

MANAGEMENT PLAN FOR IMPROVED TREE SEED PRODUCTION FROM ORCHARDS AND PROGENY/PROVENANCE TRIALS IN HAITI

by

Joel C. Timyan

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The opinions expressed herein are those of the author and not necessarily those of PADF or USAID. This document was prepared under USAID Contract No. 521-A-00-95-0030-00.

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LIST OF ACRONYMS

AFII	Agroforestry II (1987–1991), a USAID project in Haiti
ANOVA	Analysis of Variances
AOP	Agroforestry Outreach Project (1981–1987), a USAID project in Haiti
CAMCORE	Central American and Mexican Coniferous Resources Cooperative
CARE	Cooperative for Assistance and Relief Everywhere, Inc.
CASB	Centre Agricole de St. Barnabas
CBH	Convention Baptiste d'Haïti
CBP	Comité Bienfaissance de Pignon
DDA	Direction Departementale Agricole, a division of MARNDR
GLM	General Linear Model
IITF	International Institute of Tropical Forestry
IRG	International Resources Group, Ltd.
MARNDR	Ministre d'Agriculture, Ressources Naturels et Developpement Rurale
NGO	Non Governmental Organization
PADF	Pan American Development Foundation
PLUS	Productive Land Use Systems
SAS	Statistical Analysis Systems
SPSS	Statistical Programs for Social Sciences
SECID	South-East Consortium for International Development
USAID	United States Agency for International Development

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EXECUTIVE SUMMARY

This document summarizes the steps required for the production of improved tree seed in Haiti. This program is being undertaken by PADF within the PLUS project. Priorities relating to statistical analyses, silvicultural interventions and agreements with the land owners are developed for the 1999–2000 period. This phase is an extension of germplasm improvement activities that began in 1987 to establish orchards and progeny/provenance trials of important tree species used in agroforestry systems in Haiti. Fourteen sites (Figure 1 of text) containing 53 orchards and trials, were selected based on a combination of criteria including security, management capacities of the land owner and/or institution, species importance and seed production potential. These sites form the basis of a strategy to produce better adapted and genetically improved tree seed in Haiti.

OBJECTIVES

The objectives of this document were to

- Examine the new data set collected from the tree plantations in February and March 1999.
- Advise PADF on how the data should be analyzed and reported, and if further measurements should be taken before the end of 2000.
- Write a management plan for each remaining tree plantation based on the data and visits to the sites. The goal of the management plans will be to convert the tree trials to seed orchards. The plans should extend through December, 2000.
- Suggest how PADF could strengthen its relationship with the owners of the plantations and the owners of the remaining superior mother trees, so that they recognize their value (economic and otherwise) and understand their management.

In addition, electronic files containing the 1-, 3- and 5-year trial measurements for the 53 orchards and trials were transferred by the consultant to PADF computer files.

MANAGEMENT OF IMPROVED TREE SEED PRODUCTION

Aspects of orchard and trial management are discussed regarding the production of improved seed. *Trial management* requires that the original plots, separating genotypes, be maintained with permanent tags and updated maps. The importance of genotype identification is fundamental to the selection of superior families and provenances and the conversion of the trials to orchards for seed production. *Trial design* determines the orientation and placement of the genotypes that impacts breeding results and the genetic quality of the seed. Differences in trial design requires various silvicultural interventions considered necessary to meet the goals of genetic improvement and certified seed. *Flower, fruit and seed production* focuses on the optimal production of fruit rather than wood. Inputs generally not considered for wood production must be addressed and these include complete weed control; wider than normal spacing (up to 12 m by 12 m); a higher intensity of pest management and a knowledge of flower biology and pollination mechanisms that determine the genetic quality of seed. *Protocols for the production of improved tree seed* is necessary to reach agreement among the stake holders what are the conditions for improved seed, what benefits will accrue the stake holders and under what conditions such agreements are in effect. Suggestions are made concerning the scope of these protocols and the orientation of the program toward a sustainable solution. *Certified seed* is necessary to meet professional international standards and protect the investment in the orchards. A minimum requirement is that seed is source-identified, collected and handled according to professional standards, safe-guarded regarding all stages of seed distribution and properly labeled with complete provenance information.

PRIORITIES IN MANAGEMENT OF IMPROVED TREE SEED

Sites should be selected in terms of their immediate need for selective thinning and their potential to produce improved seed. This will partially depend on the flowering cycle of the species to avoid missing a year for those species who flower on an annual basis only or exhibit widely varying yields from year to year. Trials containing species that are at a comparative disadvantage on site should be replaced by species that are well-adapted and are showing a good production of seed. This improvement in orchard management is necessary to capture economies of scale and increase the potential for continued investments by the landowner. The demand for seed of the various species represented in these orchards is expected to change with time. Thus it is important to forecast change in seed demand with a shift in management priorities on a national scale. Review of current seed collection, handling, storage, data management and distribution are necessary in order to strengthen procedures that include certified seed.

DATA MANAGEMENT

A summary of the statistical procedures used to make the necessary decisions for selective thinning of the orchards and progeny/provenance trials is developed. Flow charts are provided (Annexes 6-8) that follow a step-wise process to upgrade the orchards and convert the progeny/provenance trials to orchards. An example of using the statistical procedures for a *Catalpa longissima* progeny trial is given, based on height and commercial volume data. The use of SPSS as a substitute for SAS and Microsoft Excel as a substitute for Lotus 123 is in process by PADF.

PRIORITIES IN DATA MANAGEMENT AND STATISTICAL ANALYSES

Additional variables not being measured in the trials by the regional teams were suggested based on their importance as selection criteria. These include commercial height, wind damage and an improved numerical scale for stem form. It is expected that the PADF staff will require assistance in data management, statistical analyses and interpretation which should be accompanied by in-house training. Emphasis is placed on documentation that “sells” improved seed and shows the expected economic benefits of the program. Meetings designed to improve the technical understanding of the program are suggested for the regional technical teams and the collaborating institutions.

I. INTRODUCTION

1.1 Tree Conservation in Haiti

The cultivation of trees as part of residential and agricultural systems in Haiti depends mostly on seed for propagation. But where does this seed originate? How adapted are the genotypes to the varied site conditions where the trees are typically planted? What is the commercial quality of the trees and how resistant are they to disease and hurricanes?

These questions are fundamental to the long-term health and economic basis of tree planting in Haiti. While it many seem redundant to remind the reader that trees come from forests, the challenge faced today in Haiti is that very little forest exists. What this means is that for many species, a significant portion of the best individuals have been eliminated from the breeding population. This is particularly true for species valued for wood. Seed harvested to replant trees is more likely derived from trees of lower quality with a gradual decline in economic value of subsequent generations. To make matters worse, the genetic base of the species generally narrows as selection pressures controlled by non-forest land use activities increase. The capacity of the species to adapt to changing climates, landscapes, pests and diseases is weakened with the erosion of the genetic base that constitutes a species (Namkoong, 1984) and can only be addressed by increased efforts in genetic conservation.

One way to reverse these negative trends is to manage a tree improvement program for the priority species used in Haiti and ensure that the production of improved seed is distributed to farmers. Two major goals are addressed together in the production of improved tree seed:

> 1) *The conservation of a broad genetic base to form a breeding population for future generations.*
> 2) *The selection of genotypes that exhibit superior traits associated with ecological adaptation and economic value.*

1.2 USAID-funded Tree Improvement

1.21 Phase 1 (1987–1991)

Activities associated with the improvement of tree seed in Haiti began more than a decade ago under the former USAID funded Agroforestry II project. Under contract to USAID, International Resources Group, Ltd. (IRG) began the Seed and Germplasm Improvement Project in May, 1987 which was temporarily suspended due to the failed political elections later that year. It wasn’t until May, 1988 that actual work began on the selection of superior tree candidates, the importation of a much wider genetic base of introduced species and the establishment of a series of orchards and provenance/progeny trials. The end result of project activities during 1998–1991 included:

- Selection of 660 superior tree candidates representing 40 species;
- Establishment of 52 progeny and provenance trials representing 28 species;
- Establishment of 54 seedling seed orchards representing 16 species;
- Establishment of a clonal seed orchard of *Gliricidia sepium* based on superior biomass production and survival under hedgerow management;
- Introduction of several species, selected for their potential in agroforestry systems, including *Pterocarpus macrocarpa, Terminalia ivorensis, Tabebuia heterophylla, Derris indica* and *Toona ciliata*;
- Seed collection of under-utilized native species with promising economic worth, including 2 endemic palms (*Attalea crassispatha, Pseudophoenix lediniana*), *Manilkara zapota, Chrysophyllum cainito, Zanthoxylum elephantiasis, Bumelia salicifolia, Cinnamomum montanum, Ocotea leucoxylon, Licaria triandra, Guarea guidonia, Trichilia hirta, Prunus occidentalis, Tabebuia rosea, Beilschmedia pendula* and *Omphalea triandra*;
- Data management and statistical analyses at 1-, 3-, and 5-year stages for all trials and orchards — the most complete data set of tree trials in Haiti still in existence.
- Distribution of a series of technical reports and the book *Bwa Yo: Important Trees of Haiti*, published by SECID. A list of these and other documents associated with USAID-funded tree improvement in Haiti since its inception in 1987 are provided in Annex 1. Notable documents pertaining to specific management areas relating to tree improvement in Haiti are Mesen (1988), Dvorak (1989), and Timyan (1992). These are available in the PADF library and should be periodically reviewed by the PADF staff responsible for improved tree seed production.

1.22 Phase 2 (1991–1996)

The economic embargo of 1991 completely shut down USAID-financed tree improvement efforts with the termination of the Agroforestry II (AFII) project. During this time, approximately 30% of the provenance/progeny trials and 20% of the seed orchards were eliminated due to a combination of neglect, poor site conditions and institutional instability. Between the 1992-1996 period, SECID continued to monitor 38 provenance/progeny trials and 46 seed orchards as part of the Productive Land Use Systems (PLUS) project. Five-year results of tree improvement trials for 11 species were summarized and distributed by SECID (see Annex 2). By the end of 1996, SECID ceased all management associated with the trials and orchards. The orchards and provenance/progeny trials continued to be managed more or less as tree stands by their individual owners. An additional number of trials were abandoned during this time.

1.23 PADF Improved Tree Seed Production (1999–2000)

In 1998, PADF initiated a program to combine the production of improved seed with improved management of wood lots (*rak bwa, lo bwaze*), phenological studies and the conservation of useful tree species that have become uncommon due to their over-exploitation or loss of habitat. The multiple benefits and economic justification for local sources of improved tree seed are worth re-iteration, if only to emphasize the importance of this phase of PADF's development work in Haiti.

Benefits of an Improved Tree Seed Program in Haiti

- ♦ A broad genetic base is a critical factor in the tree species' long-term resistance to new pests, diseases, environmental stressors and changing climate patterns. This is important for both introduced species (typically of a narrow genetic base) and over-exploited native species (undergoing negative selection pressures) in terms of sustainable economic and environmental benefits to society.
- ♦ The genetic gains of a particular species through recurrent selection is multiplied exponentially through the distribution of seed to decentralized nurseries, passing these gains onto the farmer in terms of increased productivity of tree products and services, long-term vigor and better economic returns. Value gains average 10–50% depending on the genetic variation of the species (Willan, 1998) and these have been confirmed in Haiti.
- ♦ The production of improved seed from local sources generates an additional tree product that is environmentally beneficial with the potential of producing income that remains in Haiti to generate further employment and wealth.
- ♦ Orchards and stands of an improved and wide genetic base established on secure land with management plans are necessary since small farmers are less likely to have the resources necessary to maintain such populations over long periods of time.

At the institutional level, the project is of interest since it attempts to integrate the mission of the DDA (Ministry of Agriculture) with community-based efforts in conserving and managing local forest resources. This includes a series of training and educational exercises that should eventually result in improved professional practice among MARNDR employees at both the provincial and parochial levels in Haiti. Ultimately, it is the responsibility of the national government to conserve the genetic heritage of economically important tree species that benefit society.

PADF hired a field coordinator, experienced with the tree improvement program since 1988, to manage the field phase of activities. He is part of a team that includes the Agroforestry Specialist and 4 PADF technicians (one for each of the 4 PADF regions). Each regional technician is being matched with a MARNDR technician seconded by the DDA to PADF activities. The regional teams have visited the 14 sites that have been selected as improved sources of tree seed. At the time of the author's recent visit to Haiti (March 29–April 12, 1999), the trials averaged 10 years and were being measured for data that would advance the program to the next stage of improved tree seed production.

II. OBJECTIVES

The purpose of this consultancy was to assist PADF in determining priorities concerning the production of improved seed from 14 sites in Haiti for the 1999–2000 period. Specifically, the scope of work included 4 objectives.

- Examine the new data set collected from the tree plantations in February and March 1999.

- Advise PADF on how the data should be analyzed and reported, and if further measurements should be taken before the end of 2000.
- Write a management plan for each remaining tree plantation based on the data and visits to the sites. The goal of the management plans will be to convert the tree trials to seed orchards. The plans should extend through December, 2000.
- Suggest how PADF could strengthen our relationship with the owners of the plantations and the owners of the remaining superior mother trees, so that they recognize their value (economic and otherwise) and understand their management.

In addition to these, the author brought to Haiti backup data files of the tree improvement program covering the 1988–1996 period. This proved to be valuable given that many electronic files, particularly database files that extend back to 1988, were either incomplete or did not survive the transfer from SECID. Most of the raw data files for the orchards and provenance/progeny trials were located and transferred from Lotus 123 to Microsoft Excel during this time (see Data Sets below). A schedule of daily activities and contacts in Haiti made by the consultant during the 2-week period is provided in Annex 3.

III. SITE LOCATIONS

A summary of the 14 sites, selected for the production of improved tree seed, is provided in Annex 4 and shown for their approximate locations in Figure 1. It should be understood that these sites represent less than 50% of the original trials that were established 1989–1991. They do not include some sites that are still available for advanced genetic selection (e.g., Bombardopolis, Nan Marron, Arnault, Pas Bonbon). Though the latter may fall outside the scope of PADF's intervention zones in Haiti, these sites are interesting from a professional perspective and should be observed for their value under a wider range of environmental conditions and as back up during poor seed crop years. Even with the optimum management of the 14 sites for seed production, *they are inadequate to meet the in-country demand for most species.*

As discussed below, options should be left open with committed landowners of these sites for expansion of 2nd generation orchards. Those species that have proven their seed production potential at a particular site would be selected. This is good business sense, if only to channel scarce resources on one site and achieve the economies of scale necessary for positive financial returns.

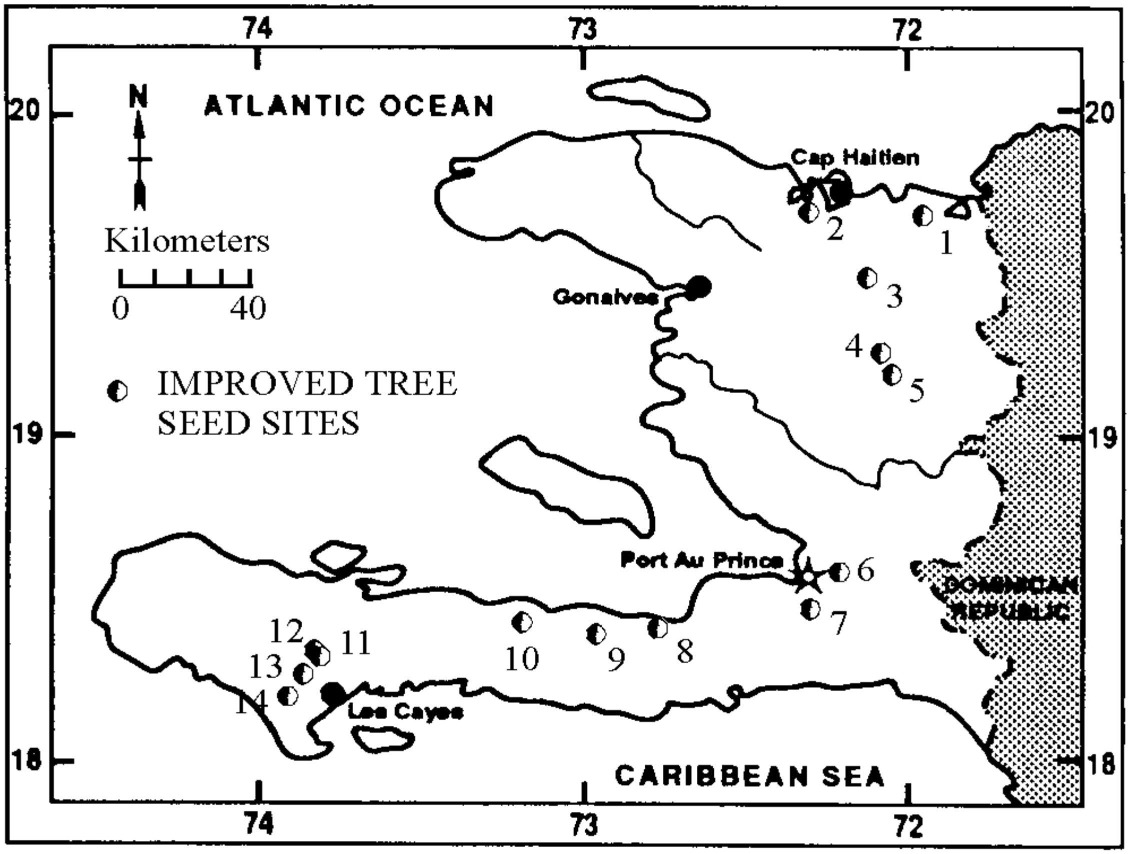

Figure 1. Sites selected for the production of improved tree seed. 1 = Terrier Rouge, 2 = Crocra, 3 = Lapila, 4 = Sapatè, 5 = Marmont, 6 = Roche Blanche, 7 = Kenscoff, 8 = Fauché, 9 = Labordette, 10 = Paillant, 11 & 12 = Laborde I/II, 13 = Pemel, 14 = Bérault.

One may ask why such sites were selected and others not? The primary consideration given to site selection in Haiti is social rather than technical. Security, both in terms of land ownership as well as tree tenure, and the motivational commitment of the landowners, mostly non-foresters, are 2 factors that will determine whether the orchards and progeny/provenance trials will accomplish their purpose. The commitment of the landowners has been tested for 10 years that included the 1991–1994 economic embargo and several political disturbances. Bi-lateral assistance which established the orchards and trials has been unreliable as a result of continual USAID policy changes and this factor alone limits the number of sites that can be realistically considered from an institutional perspective.

On the technical side, the most important criteria include the optimal matching of species with site, the silvicultural interventions that are specific to both site and species, the accessibility of the site and the uniqueness/importance of the trial in terms of its species' population.

The primary role of PADF is to provide leadership in the professional management of the trials through technical advice to the landowners and the purchase of seed for distribution to PLUS participants. Technical advice is expected to range from silvicultural procedures specific to advanced genetic selection and the optimal production of tree seed to the proper collection, handling, storage and distribution of tree seed. The final objective of producing an increased volume of improved seed should be a common goal of PADF, the DDA representing the Ministry of Agriculture and the trial owners. Once the big picture is in focus, steps required to achieve this goal should fall into place with the right balance of responsibilities and inputs by the 3 partners. This is discussed further below.

IV. MANAGEMENT OF IMPROVED TREE SEED PRODUCTION

There are several general aspects of managing the stands that should be kept in mind regarding the production of improved seed. These are discussed separately and include 1) trial management, 2) trial design, 3) flower, fruit and seed production management, 4) protocols for the production of improved tree seed, and 5) certified seed. Further insights and details are found in seed orchard management guides such as Faulkner (1975) with sections devoted to tropical species that occur in Haiti.

4.1 Trial Management

Most of the trials are missing the original stakes and identification tags that mark plots and blocks. These should be installed again, particular on confusing sites that are problematic to the inexperienced field staff or in cases where the trial maps are insufficiently precise. Accurate plot identification is critical to the selection of superior genotypes and source-identified seed production at either the family or provenance levels.

Permanent markers should at least include aluminum tags attached to selected trees (e.g., "6888-Block 1-TN 1" represents the first tree in the first block of *Cedrela odorata* provenance 6888) with aluminum nails at a height that minimizes problems with vandalism. This should be done at the same time that the trials are marked for selection of superior genotypes in 1999 and 2000. The trial maps should be updated to include the results of thinning and the elimination of genotypes.

4.2 Trial Design

Trial design determines the degree that neighbor trees are genetically related and the distribution of genotypes which in turn determines the genetic base of seed. In general, open-pollinated systems are the norm in Haiti and levels of outcrossing are largely unknown. It should not be assumed that most species represented at the 14 sites are only animal-pollinated (as common in most tropical hardwood species); wind pollination of superior genotypes is also possible and probably the case for many species. For such reason, isolation barriers are important to maintain the genetic quality of the orchards once the elimination of inferior genotypes is completed.

4.21 *Orchards*

Orchards are designed to yield genetically and physiologically superior seed or plant material for mass production. Most of the orchards in Haiti were established with the progeny of superior mother trees (i.e., half-sib families) from seed and are considered *seedling seed orchards*. (There is one *clonal seed orchard* of *Gliricidia sepium* at Lapila propagated from cuttings of superior trees at the provenance and family levels).

The orchards in Haiti are designed systematically with the condition that half-sib families are separated by a minimum of 2 non-related families. This is to maximize the likelihood of outcrossing rates under open-pollinated conditions and ensure the widest genetic base possible for breeding purposes. Generally, orchards are rogued of inferior families since this is where the greatest genetic gains are made. However, this requires properly designed progeny trials in different areas of the country in order to evaluate family performance and assess broad adaptability across sites for desirable traits. *Since this was planned, but never fully realized for most of the genotypes represented in the first generation seed orchards, it is suggested that the orchards err on the side of conserving a wide genetic base rather than eliminating a family based on insufficient evidence.* Selection would be conducted only at the individual level to maintain a vigorous stand and ensure sufficient spacing for full crown exposure to the sun. Genetic gain is not as great when “inferior” families are not rogued, but the tradeoff is that the seed will be better suited for a wider variety of site conditions.

The orchards are designed to maximize breeding combinations of superior families. It is quite likely that certain mother trees become more productive than others due to differences in microsite conditions and genotype. These individuals should be monitored closely since they will contribute a disproportionate share of the bulked seed from the orchard. Since they are also of more value to the orchard in terms of seed yield, they should be numbered so that records are sufficiently kept during seed collection.

Furthermore, certain families are likely to combine better (combining-ability) and yield seed superior in both physiological and genetic qualities. Though it is unlikely that sufficient testing will be examined to investigate such differences, this is an additional facet of improved seed that takes genetic selection one step further.

Families within orchards not represented by any other orchard or progeny trial should be conserved and only selected within family at the individual level. The conditions of each orchard site can be expected to contribute a different selection pressure (which combination of families are favored to breed) which is beneficial in maintaining a broadly adapted genetic base.

4.22 *Progeny Trials*

Progeny trials are designed to detect differences among families within a species. They are similar to orchards, except that family members are adjacent to each other (e.g., 6-tree row plots) to estimate genotype variances. Since progeny trials are more likely to show differences among families, they can be converted to orchards by elimination of the 20% poorest families and the 50-60% poorest individuals within families. The elimination of the worst performing families and selection of the top individuals within the superior families should yield much greater gains than selecting only at the individual level, as suggested for the orchards.

The progeny trials are designed to test differences among families and are not the preferred orchard design. The fact that initially there are 6 closely related trees (i.e., half- or full-sibs), the chances of inbreeding are greater since distances are minimized between family members. This would decline in importance if sufficient spacing is reserved between individuals of the same family and an adequate number of non-related families compete as pollen sources. At orchard maturity, it is likely that only the best tree of the original 6-tree family plot will be left in the orchard that will in effect eliminate the problem of inbreeding.

Caution should be taken to balance the families in terms of seed volume. It cannot be assumed that members of the same family are interbreeding. Eventually, only the most productive individual per family, in terms of seed yield, should be maintained in each family plot of the progeny trial that is converted to an orchard.

4.23 *Provenance Trials*

Provenance trials are similar to progeny trials, except that the genetic base at the species level is much broader. (The provenance trial is designed to test differences among seed sources within the natural range of the species). As such, it is more likely that genetic differences will occur for economic traits, such as wood quality or tree form. Trials are generally designed with plots that contain 16 or 25 individuals surrounded by border rows to buffer the effects of large differences in growth rates among provenances. These can be converted to seed production areas if no differences are detected at the provenance level and the trial is selected for superior individuals.

Where provenance differences are significant, the inferior provenances are eliminated and the worst trees of the superior provenances are removed to advance the genetic selection process. Tremendous gain can be expected if the worst performing provenances are removed. However, the best approach is to clone individuals of the superior provenances and establish them in an isolated seed orchard.

Widely diverse provenances should be maintained separate if such differences are important in site adaptability or economic traits. Seed orchards would be established to maintain genetic homogeneity and superiority at the provenance level. Genetic material may derive from selections made in Haiti provided that measures are taken to maintain accuracy in provenance identification. Alternatively, it is advised to purchase seed from orchards of established tree improvement programs in countries of origin or where the particular provenance has been selected for superior traits in advanced generations. Provenance information should be required to accompany the genetic material and kept safe for future reference.

As provenances and individual trees within provenances are culled for the conversion of these trials to orchards, an excellent opportunity exists to examine wood quality. Samples are taken of the different provenances for testing among master woodworkers qualified to make professional judgments of desirable characteristics. This will be especially important to dispel (or support) suspicions regarding the inferior quality of rapidly grown wood or introduced provenances relative to native ones.

4.24 *Arboreta*

Arboreta are designed to display a large selection of tree species and allow them to grow together on one site. The arboreta established by SECID followed a completely randomized design, each species planted as a single tree and replicated 20–30 times. Theoretically, the species have equal chance of growing next to each other. The most useful aspect of arboreta is to observe the relative growth of species together on one site, to study their phenological patterns and to exhibit a wide range of useful species as an educational tool. An additional role of the arboreta is that they are host to several uncommon native tree species as well as recently introduced species to Haiti. For highly visible arboreta that might be used for instructional purposes, it is advised to tag individuals with their proper names and genetic origin.

Over time, a particular site can be expected to favor certain species over others. The arboreta established on the more favorable sites, such as Fauché, need to be thinned and it is at this time that consideration be given to the slower growing species. Species diversity, rather than seed production or wood yield, is the goal. Therefore, only the best individuals of each species should be maintained on site after thinning with approximately an equal number of individuals per species. Certain species will obviously be selected for removal due to their poor performance if they have not already been eliminated through natural selection.

Seed from arboreta can be collected for species that are difficult to locate in-country, though such seed should not be mass propagated. As a source of seed, recent introductions should be considered with caution due to their narrow genetic base and lack of information regarding their ecological function under widespread use.

Individual trees should be pruned to remove diseased limbs or shape crowns that might allow a higher tree density at maturity. Pruning should take place during the height of growing season rather than at either the beginning or end to avoid undue stress on the seasonal energy balance of the tree.

4.3 Flower, Fruit and Seed Production Management

Perhaps the most difficult aspect of managing the stands for optimal seed production is that it is more akin to fruit tree management rather than wood tree management. Exposure of the crown to full sun conditions will require wider spacing (up to 12 m X 12 m) for larger crowned species at maturity than normally considered when managing for high-value wood production. This in turn will entail that tree and land security considerations are carefully evaluated for species not generally considered as fruit trees. Crown shaping and interventions to promote flowering and fruiting might be comparable to tropical fruit species, though it should be cautioned that this too can affect the proportion of male/female flowers, degree of selfing and other physiological responses that affect seed yield (Werner, 1975). Controlled pollination techniques should not be overlooked as a method to increase flower set and favor certain genetic combinations of select trees.

Flower biology is an aspect of orchard management that should be understood. This is briefly summarized in Table 2 for major species represented at the sites. The proportion of female (pistillate flowers) to male trees (staminate flowers) in an orchard for dioecious species will affect seed yields and should be managed accordingly. If it can be determined that male trees can be eliminated without upsetting the family balances or decreasing fruit set of the female trees, this should be considered to give more room to the female trees. Knowing the sexuality of a particular species gives no indication of self-compatibitility (whether a species is selfed under natural conditions) nor average outcrossing rates (proportion of seed that is crossed with neighbors). However, the scientific literature supports that tropical and sub-tropical trees are largely self-incompatible and tend toward being outcrossed (Bawa et al., 1985; Bullock, 1985; Styles, 1972). As more information of this type becomes available to the technical team, it should be used in the improved management of the orchards. Many of the species have been studied for such information and should be available in the forestry literature.

For the most part, the trials have been maintained by the landowners as tree stands only, varying widely in management intensity. Thus, certain factors that limit their productivity (grazing, periodic harvesting of trees, fire, weeds) need to be addressed with the landowners on a site by site basis. Invading weeds, particularly woody species that have become established in the orchards and trials, need to be eliminated completely by stump removal. Unselected trees of the same species that occur in the vicinity of the orchard should be eliminated to avoid contamination via wind or insect pollination. A distance of up to 100 m should be sufficient to isolate the orchard from such sources of contamination. This distance may be decreased if a barrier comprised of different, non-hybridizing species occur between the orchard and trees of the same species.

Table 2. Sexuality of selected species represented in the orchards, progeny and provenance trials included in this report.

SPECIES	SEXUALITY
Acacia auriculiformis	Hermaphrodite[1]
Azadirachta indica	Polygamous[2]
Calliandra calothrysus	Hermaphrodite
Calophyllum calaba	Dioecious?
Casuarina equisetifolia	Monoecious[3], dioecious4
Catalpa longissima	Hermaphrodite
Cedrela odorata	Monoecious
Colubrina arborescens	Hermaphrodite
Cordia alliodora	Hermaphrodite
Enterolobium cyclocarpum	Hermaphrodite
Eucalyptus camaldulensis	Hermaphrodite
Gliricidia sepium	Hermaphrodite
Grevillea robusta	Hermaphrodite
Leucaena leucocephala	Hermaphrodite
Lysiloma sabicu	Hermaphrodite
Pinus caribaea var. hondurensis	Monoecious
Senna siamea	Hermaphrodite
Simarouba berteroana	Dioecious
Simarouba glauca	Dioecious
Swietenia humilis	Monoecious
Swietenia macrophylla	Monoecious
Swietenia mahagoni	Monoecious

[1]Bisexual flowers with stamens and pistils in the same flower. [2] Unisexual and bisexual flowers on the same tree. [3] Flowers unisexual, staminate (male) and pistillate (female) flowers on the same tree. [4] Flowers unisexual, staminate (male) and pistillate (female) flowers on different trees.

The orchards should be monitored closely for flower and seed production and thinned to ensure the proper development of crowns for maximum fruit yield. With the emphasis on optimal conditions for flowering, fruit production and seed yields, it is foreseeable that some application of pesticides might be desirable if certain precautions are taken. The biggest risk in using pesticides, particularly wide spectrum, is the potential harm to beneficial insects that pollinate the trees. Only in severe cases of pest infestations should insecticides be considered. Most of the control of insect pests should be managed using integrated pest management procedures and maintaining sanitary conditions to avoid pest outbreaks. Fungicidal sprays may be helpful in the more humid areas to maintain productive flowering branches, but this should be integrated with proper pruning techniques to favor strong fruit-bearing branches. Pruning should be done according to prescribed methods for tropical trees and local environmental conditions.

Fertilizer and irrigation treatments, when available, should be considered to optimize flower set and seed production. This might be done as amendments to mixed cropping associations designed to make the land more profitable and maintain security.

4.4 Protocols for the Production of Improved Tree Seed

Most of the landowners volunteered their land on good faith after it was understood the goal of trial or orchard establishment. Many have sacrificed renting the land or using it for more lucrative agricultural pursuits, maybe with the hope that the trees would offer an acceptable return on investment. It was certainly questionable at the time of trial establishment that anything would ever come of the trials. The economic embargo and the political nature of USAID support only supported their suspicions. Now that a decade has past and the trees of many trials are approaching harvestable age, the critical task of selling the idea of improved seed production is at stake.

A simple protocol is necessary to clarify the goals and objectives of the orchards; to set conditions for the management of trees and the purchase of seed; to clarify the role of the landowner and the supporting institutions (PADF and the DDA) in the production of tree seed; and to strengthen an agreement that is considered a win-win solution for each partner. It will be very important for PADF and the landowners to agree what the conditions are for improved seed, what benefits will accrue the landowner and the client (PADF or other seed purchaser) and under what conditions such agreements are in effect. These agreements should be made directly with the landowner and be specific for each landowner and/or institutional structure. Specific issues regarding certified seed should be developed only after a commitment is made to meet basic standards of seed production.

4.41 *Conditions for Improved Tree Seed*

The concept of improved seed is founded on the principles of tree improvement. Though improved seed addresses both physiological and genetic parameters, only the latter is being considered at this time. In order for tree seed to be considered “improved”, there are at least 3 parameters that should be satisfied:

1) Genetic base must be identified to parentage, as indicated on provenance or pedigree summary sheets;
2) Genetic superiority must be evidenced by scientific data, include confidence levels and a degree of selection intensity to rogue inferior trees at the provenance, family or individual levels;
3) Seed must be accompanied by verifiable source information, including date of harvest, number of trees harvested, parentage, seed collectors, orchard location and physiographic parameters. The details of source-identified material and ensuring chains of custody is paramount to certified seed, giving such seed the premium value that distinguishes it from ordinary tree seed.

It cannot be assumed that the primary interest of the landowners is the production of improved tree seed or that they have an adequate understanding of the objectives and goals of sound tree population management. This is not to be expected, but a better understanding of the priniciples involved can only enhance their continued commitment and better management of the orchards in years to come.

4.42 *Economics of Improved Seed Production*

The evaluation of the trials in terms of seed production should begin immediately, regardless of whether the seed is considered "improved" as a result of selective thinning. This should be done with the landowners to allow them to estimate the variation in seed crops, current yields and financial returns. This begins the process of estimating the management costs of an orchard. The participation of the landowners is crucial, since it is their choice whether the trials remain in seed production or the land is converted to some other use.

A positive financial return may not be necessary for some landowners. However, the orchards should be able to pay for themselves at competitive land rents and alternative land use options, and should include the stumpage value of the trees as an asset. If seed sales or a suitable combination of land use options is not favorable, there is obvious pressure for the landowner to shift out of trees.

The silvicultural interventions required to cull inferior families or promote optimal flowering and seed production may not be preferable from the perspective of the landowner. It's not unlikely that some of the landowners will request that the additional costs associated with the genetic upgrade of their trees be financed in part by PADF. PADF should determine to what degree an incentive package is required. This will be determined by the social status of the landowner, the productivity and value of the annual seed harvest and the motivational level of the landowner to manage the orchard.
It is foreseeable that some landowners will see an opportunity to cultivate mixed crops under the open site conditions of widely spaced trees (up to 12 m x 12 m) and consider this benefit to be sufficient for culling inferior trees.

Options should be left open with committed landowners of these sites for expansion of 2nd generation orchards for those species that have proven their seed production potential at a particular site. This makes business sense, if only to channel scarce resources on one site in order to achieve the economies of scale critical for positive financial returns. For example, the environmental conditions at Lapila seem to favor seed production of *Gliricidia sepium* relative to other sites in Haiti. This is a comparative advantage for this site. Other species located at this site, such as *Catalpa longissima* and *Senna siamea*, are at a comparative disadvantage. Thus, it should be beneficial to convert the entire *Catalpa longissima* and *Senna siamea* trials to a second clonal seed orchard of *Gliricidia sepium*.

No economic analysis has been conducted for genetically improved tree seed production in Haiti. While this is hypothesized to be favorable, it is certain that the economic gains would not accrue to the orchard owners sufficiently to compete with the current array of seed contractors. The latter do not generally incur costs associated with land or tree security or meet the conditions required for source-identified seed and the silvicultural interventions that are required for genetically improved seed. PADF will have to determine with each landowner the margin that is expected to meet costs plus a reasonable profit. This should be somewhere near the international market for genetically improved seed.

4.5 Certified Seed

Certified seed is generally accepted as reproductive material of proven genetic quality, superior in one or more economically important traits (Barber, 1975). In the strictest sense, it cannot be expected that professional standards responding to laws governing the collection, distribution and use of forest tree seed in European and North American countries be applied to the situation in Haiti. However, it should be agreed that certain minimum requirements are met:

1) Identification of source material, including origin and *ex situ* genetic base;
2) Prescribed collection, handling, processing and storage conditions by species;
3) Chain-of-custody agreements between orchard owner or manager and seed purchaser or broker;
4) Labeling protocol, include distinctive packaging (to separate certified seed from non-selected seed), necessary provenance information and selective criteria upon which improvement is based.

It will be necessary to ensure that the above conditions are met in order to begin the process of certified seed. It should be expected that the DDA understand the economic importance of certified seed and the institutional commitments necessary to maintain this approach. All personnel involved in the production of certified seed should be aware of the strict conditions that must be met in order for the program to work. This might include a governing board comprised of members representing the orchard owners, the government of Haiti and the NGO community. Safe guards to protect certified seed against the claim of non-certified seed collectors should be controlled and monitored by the governing board.

4.6 Priorities in Management of Improved Tree Seed

4.61 *Site Priorities*

Sites should be selected based on their potential to yield improved tree seed and species demand. Several orchards and trials are past due in terms of selective thinning and these trials should take priority over the less developed trials. Statistical analyses, interpretation and recommendations for selective thinning, management protocols, and training of the regional teams should proceed as rapidly as possible in an attempt to miss as few full cycles of flowering and fruiting. This is particularly true for those species that do not fruit consistently from year to year.

Conventional site maintenance procedures, such as weeding and culling out of invading non-orchard trees, may begin prior to selective thinning. Timing of any of the necessary silvicultural interventions will require close planning with the land owner since precautions are needed in terms of security. Security problems should be addressed with innovative social arrangements and the planning of silvicultural interventions.

The evaluation of each site, particularly in terms of recommendations for improved management by the land owner and caretakers, will be necessary to accompany the protocol that is developed for each site. A draft of the recommendations and protocol should be discussed in detail and encourage the input of all participants prior to finalization and signatures.

4.62 *Species Priorities*

Progeny and provenance trials of species that are at a comparative disadvantage in terms of seed production potential should be replaced by orchards of better adapted species. This is an excellent opportunity to establish 2nd generation orchards with clonal material (*Gliricidia sepium, Cedrela odorata, Catalpa longissima, Cordia alliodora*) and train the regional teams in such techniques. For most species, there is insufficient acreage in Haiti devoted to improved tree seed production. The addition of more productive orchards expands the marginal rate of return by capturing economies of scale while strengthening the institutional relationship with the owners.

Certain species may be in higher demand than others or are unique in the sense that they are represented by only one orchard in Haiti. An analysis should be done regarding the potential of seed demand as it changes with the temporal demand of NGOs and government agencies working in new areas of the country. The proposed seed catalogue would assist in publicizing the availability of seed to the forestry and agroforestry community and enhance demand that should support seed prices.

4.63 *Seed Collection, Handling and Storage*

The proper collection, handling and storage of seed should be reviewed for areas of improvement (Willan, 1987; Timyan, 1990). Training to meet the demands of a certified seed program is necessary in order to establish the ground rules and take the necessary precautions for a reputable and professional system. Design of distinctive packaging should accompany the development of the certified seed component.

The regional teams should be instructed in the selection and collection of tree seed from plus trees in their region. Regional nurseries can benefit from the harvest of these trees after agreement with the tree owner for harvest rights. Sufficient benefit should accrue the tree owner and seed harvests from plus trees can supplement the production of improved seed from the orchards. Species that can be propagated through cuttings should be multiplied as clones from plus trees with farmers that would best benefit from improved management (i.e., sawyers, woodworkers, carpenters).

V. DATA MANAGEMENT

5.1 Data Sets

The back up of the original data sets covering the 6, 12, 24, 36 and 60 month measurements for most of the trials at the 14 sites was completed during the consultant's stay in Haiti. These data sets proved to be critical since most of the original data sheets were lost or misplaced during the transfer of files from SECID to PADF. Data integrity and authentication of provenance source is fundamental to an improved tree seed program and cannot be over-emphasized.

The trials are being measured using the same procedures that were developed previously under the IRG/SECID program (1988–1996). The PADF coordinator has trained the regional teams in tree measurements and has participated in the actual measuring of the trials during the recent 10–year measurement period. Individual tree measurements include total tree height, basal diameter, diameter-at-breast height, crown diameter, tree status, and phenological status regarding leaves, flowers and fruit. All these parameters are useful to detect differences among genotypes and select desirable traits for genetic improvement.

The data collection sheets of several trials were checked for neatness, completeness and accuracy in computer entry. The author did not have the time to confirm the accuracy of field measurements, though the level of precision should be periodically checked for each technician that is responsible for measuring. This can vary tremendously from one technician to another and ultimately determines the confidence placed in statistical analyses and interpretation. At the least, each field technician should understand the possible sources of error in trial data. A reasonable compromise between speed and accuracy is the goal.

It was noted that trial sheets were often incomplete for "boiler plate" information such as trial name, date of measurement, and name of technician. Even tree position within plot was lacking on a number of data sheets. No matter how tedious the labeling of this information may appear to the field personnel, it is important in the event that data sheets are separated from each other. This is particularly true if the data are being entered by someone other than the person who collected it.

The orchards, progeny and provenance trials average 10 years in age, but hadn't been measured for 5 years. During the re-measurement period, the field coordinator was able to determine the proper order of measurement for most trials. However, several trials were identified for re-measurement after it was determined that the same order of measurement was not followed. Normally, copies of the original data sheets are taken to verify tree position and order of measurement. However, I was told that these sheets were not saved, so the electronic files and original maps are the only way to safely re-construct this information.

5.2 Statistical Analyses and Interpretation

5.21 *Summary Statistics*

Summary tables of descriptive statistics were developed at SECID using SAS programs and outputs, followed by a WordPerfect macro that allowed the information to be inserted into easy-to-read tables. An example of such a table is included in Annex 5. Similar procedures should be worked out for Excel, SPSS and Word. In addition to the current statistics, each trial should have a location map, a trial layout map, a provenance sheet that indicates the parentage of the genotypes, and past statistical summaries. The original compilation of this basic trial information was lost or misplaced during the shutdown of the SECID office in 1997/98.

5.22 *Quantitative versus Qualitative Traits as Selection Criteria*

Though heritabilities of desirable traits are unknown for most of the species being considered, it is generally true that qualitative traits (form, branch pattern, crown development) are more likely to be inherited than quantitative traits (height and stem diameter). This is because the latter parameters are more sensitive to microsite differences and stem density relationships that mask genotype differences. Thus, a tree of superb form is generally selected over a tree of greater girth with inferior form. Stem form, branch pattern and commercial volume (largely controlled by stem form and forking pattern) are selected in favor of height and stem girth as criteria for judging the superiority of families or provenances. This is not to say that survival and vigor differences are not important criteria, but that they are weighted less than desirable qualitative traits.

5.23 *Using Statistics as a Management Tool*

Not all the trials will be rogued (eliminated) at the family or provenance level, particularly if there is no statistical evidence to support such a decision. On the other hand, if genotype variation is large enough to show superiority, then the inferior families or provenances should be eliminated. To facilitate the step-wise process of making these decisions for each trial type, a series of flow charts were developed (Annexes 6–8).

Using the flow chart approach, the core statistical analyses required to test for genotype differences are the Analysis of Variance (ANOVA) and a means comparison test, such as the Waller-Duncan test. The first is to test the significance of the null hypothesis – that there are no differences among genotypes (i.e., Are progeny =?; Are provenances=?). The second is to rank the genotypes and determine which means are significantly different.

Once the ANOVA and means comparisons tests are conducted, the next step is to eliminate the poorest 20% of the families or provenances if such differences are shown to be significant for the desired trait or combination of traits (e.g., form, commercial volume). The family or provenance distribution of the top 100-200 individuals ha^{-1} is conducted by sorting the individual trees in descending order. The number of individuals per family should be more or less equal after selection. If no differences are shown, all families are retained in the trial and selection is conducted only at the individual level.

Time did not allow during the consultant's stay to practice such analyses using SPSS. Though the statistical terminology may not be similar to SAS, there should be no major difficulties in using SPSS.

Finally, it should be stated that there are errors involved in interpreting the statistical analyses. This comes with experience and an understanding of the field conditions that might confound trial results. For example, if no statistical differences are detected among genotypes because homogeneity within blocks was a problem, the trial is generally considered a failure. However, for purposes of improved seed production, the trial is upgraded by selection at the individual level. Though less genetic gain can be expected, the genetic base is conserved for adaptability on a wider range of sites.

5.24 *An Example of Statistical Analyses and Interpretation*

An example of how the 10-year trial data should be analyzed and interpreted follows for the *Catalpa longissima* progeny trial at Laborde. This trial contains 13 families and the decision needs to be made whether all families are retained and if so, how many individuals should be culled. Statistical analyses were conducted using SAS procedures for General Linear Model (GLM) and the Waller-Duncan k-ratio Test.

First, height data was analyzed for significant differences among families. The results of the GLM procedure showed that there was insufficient evidence to reject the null hypothesis - that there were no differences in family heights. Second, an index for commercial volume was calculated for each tree using the formula: Commercial Volume = ((Commercial Height)*100)*(DBH^2)/10,000, where Commercial Height is measured in meters, DBH is measured in centimeters and Commercial Volume is in units of $10^{-2}\,m^3$. (Commercial height refers to the usable portion of the tree stem for either posts, poles or lumber). The commercial volume data was analyzed for significant differences among families. The results of the GLM procedure showed that there was sufficient evidence to reject the null hypothesis and that the test was highly significant ($Pr > F$ 0.0001). The Waller-Duncan Test ranked the families in descending order and estimated the minimum significant difference that must exist between families to show a difference (see Annex 9 for a summary of the statistical results).

Since commercial volume is more important than height data when comparing families, this variable is used to distinguish the superior families from the inferior families. When comparing the 5-year results with the 10-year results, the families fall broadly into 3 categories:

1) Families that are consistently superior (104, 117, 105, 123);

2) Families that change rank (111, 122, 103, 118, 110, 124, 125);
3) Families that are consistently inferior (159, 169).

The two poorest families (159, 169) should be eliminated which leaves 11 families in the trial. Each family that is left is then selected at the individual level, leaving 2 trees per family plot and a final spacing of approximately 18 m^2 $tree^{-1}$. (Original spacing was 6 m^2 $tree^{-1}$). If it is decided that yet a wider spacing is required for full exposure of the crowns and maximum seed production, then an additional thinning can be conducted.

Overall, this selection strategy conserves a sufficient genetic base while attempting to make genetic gains in the species. Selection is conducted at both the family level (families 159 and 169 are rogued) and at the individual level (2/3 of the individuals are removed).

5.25 *Priorities in Data Management and Statistical Analyses*

The greatest areas in need of improvement regarding data management and statistical analyses include the following:

1) Additional variables of commercial height, measured in 0.1 meters, and a category for wind damage, suggested "28" to compare with other "Tree Status" categories, are recommended. Commercial height, usually height to the primary fork, is an important indicator to evaluate differences among genotypes for high-value lumber species. Though for some species the measurements taken at 5 years may still be valid (*Catalpa longissima, Swietenia* sp.), this variable should not be assumed to stay constant. For the single-boled species, commercial height increases as the height to the minimum top diameters increase (*Pinus, Cordia alliodora,* some *Cedrela odorata* provenances). Whereas *Catalpa longissima* families might not exhibit significant differences among mean heights or basal areas, they have been shown to test difference for commercial stem volumes (see Timyan et al., 1997). In this case, commercial height was significantly different among families. I suggested to the field coordinator to re-measure the lumber species for commercial heights prior to final assessments, though the measurements for 5 years can be used as rough estimates if field time does not allow.

Wind resistance is an important trait for hurricane-prone climates such as Haiti. Theoretically, native species have been selected over time for resistance and this should be one of the selective criteria for newly introduced species and provenances.

It is also recommended that the form codes be changed to a score that is scaled according to quality, especially for the top construction wood species. As it stands now, 0 = straight; 1 = crooked; 2 = forking below 1.3 m; 4 = lumber. These are too vague and does not follow a logical progression for statistical analysis. Furthermore, the score are not sufficiently precise for the selection intensities necessary for improvement. An alternative scoring system follows more conventional methods (Ledig and Whitmore, 1981) as explained in Table 1.

Table 1. Stem form scoring system for select-tree candidates.

Score	Explanation
0	Perfectly straight without sweep, crook or spiral.
1	Quite straight but with gradual sweep.
2	Somewhat crooked or with spiral form; offset from stem axis less than DBH.
3	Badly crooked or spiral form; offset from stem axis greater than DBH.
4	Very badly crooked, with fork above 1.3 m.
5	Very badly crooked, with fork below 1.3 m.

2) The staff responsible for data management will require assistance in the statistical analyses and interpretation of the data. The minimum amount of data transformations and statistical analyses would include:

- Summary tables for 10 year data sets, by species, provenance or family as shown in the example for 5 year results of a *Cordia alliodora* provenance trial in (Annex 5);
- Analysis of Variance (ANOVA) or General Linear Models (GLM) and Waller-Duncan means separation tests for height, basal area, commercial volume index (Dbh^2 * commercial height), and form variables as shown in the example of 10-year results of the *Catalpa longissima* progeny trial at Laborde (Annex 9);
- Estimating wood volumes and biomass weights using available equations as published in Timyan (1996) for species primarily harvested for charcoal and fuelwood. It is useful to run ANOVA and means comparison tests on wood volumes of multi-stemmed or large-crowned species (*Gliricidia sepium, Leucaena leucocephala glabrata, Acacia auriculiformis, Senna siamea*);
- Presentation of data in graphic forms and tables for reporting evidence that supports the improved genetic quality of selected genotypes at either the provenance or family levels, as shown in Table 3 of the *Catalpa longissima* report (Timyan et al., 1997) or the corresponding histogram below in Figure 2.
- A loose-leaf file folder containing for each trial i) provenance sheet (indicating the pedigree or origin of the seed), ii) location map, iii) trial map, iv) statistical summary sheets for 5- and 10-year measurements and v) a log of trial visits with brief summaries of activities accomplished including measurements and silvicultural interventions.

3) A brief meeting should be planned regularly with the regional teams so that they are aware how the trial measurements and statistical analyses/interpretation of the data fit into the overall goal of improved seed production. The overall sequence of events for each site should follow i) 10-year measurement period; ii) statistical analyses, interpretation and conclusions; iii) silvicultural interventions to upgrade or convert trial to improved seed production status; and iv) the harvest, handling and distribution of seed through the PADF seed center. Strengthening of data management, computer and statistical skills by office personnel should be addressed through intensive workshops or sub-contracted out to professionals if scheduling conflicts and time is limiting progress.

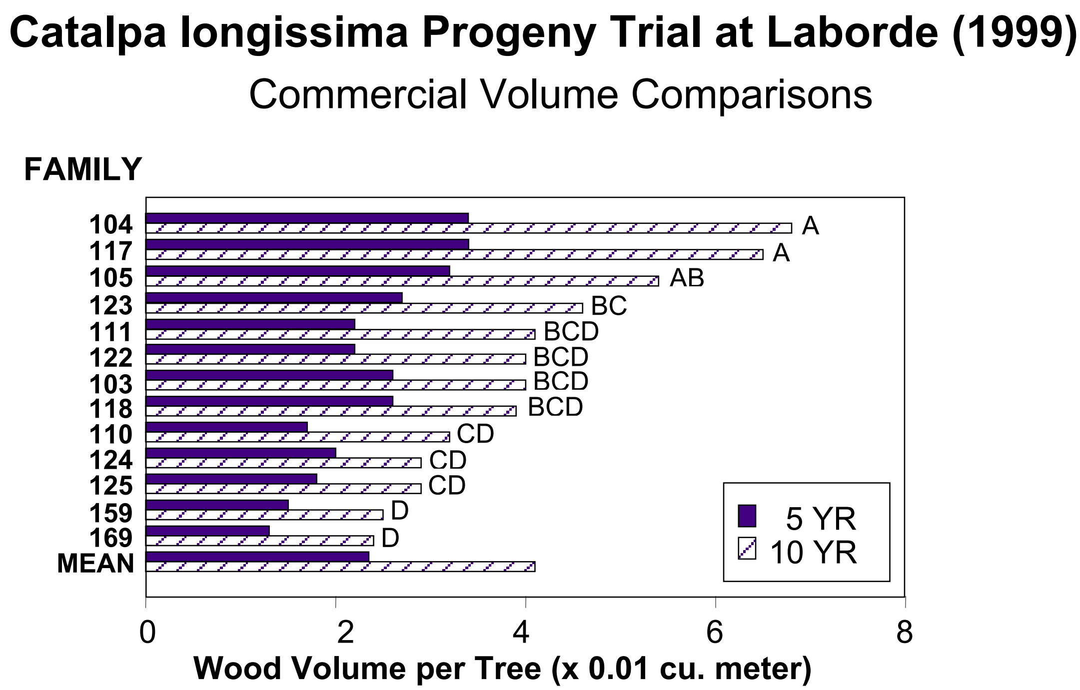

Figure 2. Example of 5- and 10-year comparisons of mean tree wood volume by family. Family means followed by the same letter are not significantly different at P = 0.05.

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GLOSSARY

ARBORETUM a place where a diversity of tree and shrub species are grown for exhibition or study.

AGROFORESTRY the cultivation of trees with food crops and livestock.

BIOMASS the total mass or amount of living organisms or material in a particular area or volume.

BISEXUAL a flower with both male (stamens) and female (pistils) reproductive organs. Also known as perfect flowers.

CERTIFIED SEED seed of proven genetic quality, superior in one or more economically important traits.

CLONE a group of cells derived from a common ancestor; applied to trees propagated by vegetative means to produce genotypes identical to the parent.

COMBINING ABILITY the capacity of a genotype to exhibit a character or group of characters when crossed with another genotype.

DIOECIOUS a tree (or plant) with unisexual flowers (staminate and pistillate) on different trees.

ENDEMIC native to a particular country, nation, or region.

GENOTYPE the hereditary constitution of an individual organism.

GERMPLASM the total availability of genetic material for a particular species.

HEREDITY the transmission of characteristics from parent to offspring by means of genes in the chromosomes.

HERMOPHRODITE a tree (or plant) with pistils and stamens in the same flower; bisexual; monoclinous.

INBREED to breed by continual mating of individuals of the same or closely related genotypes.

MONOCLINOUS having stamens and pistils in the same flower.

MONOECIOUS a tree (or plant) with unisexual flowers (staminate and pistillate) on the same tree.

POLLINATION the transfer of pollen from the anther to the stigma.

ORCHARD an area of land devoted to the cultivation of fruit trees. Seedling seed orchards are established with seedlings derived from seed. Clonal seed orchards are established with seedlings derived from cuttings, tissue culture or other type of clonal material.

OUTCROSS the transfer of pollen from the anthers of the flowers of one tree (or plant) to the stigma of the flower of another tree (or plant).

PHENOLOGY the study of natural phenomena that recur periodically, as flowering and fruiting of tree species, and their relation to climate and changes in season.

PHENOTYPE the appearance of an organism, such as a tree, for a character or group of characters as a result of the interaction between genotype and the environment.

PISTILLATE bearing a pistil or pistils, but lacking stamens.

POLYGAMY unisexual and bisexual flowers on the same tree.

PROGENY the subsequent generation following a mating or crossing of parents.

PROVENANCE origin; source; generally applied to the origin of a population within a species defined by barriers that inhibit gene flow and consequent differences in allele frequencies.

ROGUE to eliminate; normally applied to the elimination of genotypes at the family or provenance levels.

SELECTION any process, natural or artificial, by which certain organisms or characters are favored or perpetuated in preference to others.

SELF-COMPATIBILITY self-fertile; ability to produce fertile offspring as a result of selfing.

SELFING self fertilization of an organism.

SIBLING (full v. half) family member sharing one parent (half-sibling) or both parents (full-siblings).

SILVICULTURE the art of cultivating a forest.

STAMINATE bearing stamens but not pistils, as a male flower which does not produce fruit or seeds.

UNISEXUAL a flower with either male or female reproductive parts, but not both. The term is also applied to trees (or plants) possessing such flowers.

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CONSULTANT'S SCHEDULE IN HAITI FOR THE PERIOD MARCH 29 – APRIL 11, 1999.

DATE	LOCATION	ACTIVITIES
Mar 29	Port-au-Prince	Arrive AA 1291; M. Bannister residence
30	Port-au-Prince	PADF office; mtg. w/ M. Bannister, E. M. de Béliard, Y. Elie
31	Port-au-Prince	PADF office; transfer database files
01	Port-au-Prince	PADF office; database management
02	PAP-Cayes	Fauché, Paillant and Laborde sites
03	Cayes	Pemel (measure Block IV), Laborde (confirm superior ranks)
04	Cayes	Bérault, Pemel selection strategy, Oblat Fathers, Camp Perrin
05	Cayes-PAP	Cayes-Arnault-Paillant-PAP
06	Port-au-Prince	PADF office; Double Harvest nursery/orchards; Thomazeau trial
07	Port-au-Prince	PADF office; database transfers and management
08	Port-au-Prince	PADF office; database management; report write-up
09	Port-au-Prince	PADF office; database management; report write-up
10	Port-au-Prince	Bannister house; report write-up; meet with Rouzier and Berrouet
11	Port-au-Prince	Depart PAP on AA 1646

SUMMARY OF 14 SITES CONTAINING TREE IMPROVEMENT TRIALS, SEED ORCHARDS AND ARBORETA GROUPED ACCORDING TO PADF REGIONS.

SITE LOCATION	OWNER	EST. DATE	SPECIES	TRIAL TYPE	NO. FAMS ***NO. PROV*** NO. SPECIES	S[!]	M	B	A	U
			PADF REGION 1 (CAYES)							
PEMEL	Gaspard Brice	5.89	*Cordia alliodora*	provenance	***4***			*	*	*
		5.89	*Enterolobium cyclocarpum*	provenance	***4***			*	*	*
LABORDE 1	Homer Fanfan	4.89	*Cedrela odorata*	provenance	***8***	*		*	*	*
		4.89	*Catalpa longissima*	progeny	**13**	*		*	*	*
LABORDE 2	Plantel Fanfan	4.91	*Simarouba glauca*	orchard	**10**			*	*	*
		4.91	*Simarouba berteroana*	orchard	**5**			*	*	*
BERAULT	Albert Alexis	4.89	*Cordia alliodora*	provenance	***5***		*	*	*	*
		4.89	*Cedrela odorata*	provenance	***8***		*	*	*	*
		4.89	*Swietenia humilis*	provenance	***2***		*	*	*	*
		4.89	*Swietenia macrophylla*	provenance	***2***		*	*	*	*
			PADF REGION 2 (JACMEL)							
LABORDETTE	S. J. Francois	5.89	*Cedrela odorata*	provenance	***7***			*		*
		5.89	*Swietenia macrophylla*	provenance	***2***			*		*
		5.89	*Catalpa longissima*	progeny	**13**			*		*
FAUCHE	A. Gattereau	7.90	20 species	arboretum	20	*	*	*	*	*
PAILLANT	J. Deschamps	4.91	37 species	arboretum	37	*	*		*	*
		4.91	*Calophyllum calaba*	orchard	**4**	*	*		*	*
		4.91	*Simarouba berteroana*	orchard	**3**	*	*		*	*
		4.91	*Grevillea robusta*	provenance	**30** (***4***)	*	*	*	*	*
		4.91	*Acacia auriculiformis*	orchard	***10***	*	*	*	*	*

SITE LOCATION	OWNER	EST. DATE	SPECIES	TRIAL TYPE	NO. FAMS ***NO. PROV*** NO. SPECIES	S[!]	M	B	A	U
			PADF REGION 3 (CAP HAITIEN)							
CROCRA	M. Laroche	11.89	*Catalpa longissima*	progeny	**8**	*		*	*	*
		11.89	*Lysiloma sabicu*	progeny	**8**	*		*	*	*
TER. ROUGE	St. Barnabas	11.90	25 species	arboretum	23	*	*		*	*
		11.90	*Acacia auriculiformis*	orchard	**5**	*	*		*	*
		11.90	*Senna siamea*	orchard	**6**	*	*		*	
		11.90	*Catalpa longissima*	orchard	**22**	*	*		*	*
		11.90	*Eucalyptus camaldulensis*	orchard	**3**	*	*	*	*	
LAPILA	C.B. Pignon	5.91	*Gliricidia sepium*	cl. orchard	**100**	*	*	*	*	*
		10.89	*Lysiloma sabicu*	progeny	**15**	*	*		*	*
		5.89	*Catalpa longissima*	progeny	**23**	*	*		*	
		5.89	*Simarouba glauca* I	progeny	**7**	*	*		*	
		5.89	*Senna siamea*	provenance	***7***	*	*		*	
		5.91	*Acacia auriculiformis*	provenance	**5 (*10*)**		*	*		*
		5.91	*Acacia auriculiformis*	orchard	**5 (*10*)**		*	*		*
		5.89	*Casuarina equisetifolia*	provenance	***3***	*	*		*	*
		5.89	*Enterlobium cyclocarpum*	provenance	***3***	*	*		*	*
		5.89	*Leucaena* K varieties	provenance	***6***	*	*		*	
			PADF REGION 4 (MIREBALAIS)							
MARMONT	C. B. d'Haiti	8.90	25 species	arboretum	25				*	*
		8.90	*Calophyllum calaba*	orchard	**21**				*	*
		8.90	*Senna siamea*	orchard	**13**		*	*	*	
		8.90	*Eucalyptus camaldulensis*	orchard	**3**	*	*	*	*	*
		8.90	*Swietenia* hybrid	orchard	**12**	*	*		*	*
SAPATE	Arnold Sylvain	5.91	*Acacia auriculiformis*	orchard	**5 (*10*)**	*	*	*	*	*

SITE LOCATION	OWNER	EST. DATE	SPECIES	TRIAL TYPE	NO. FAMS ***NO. PROV*** NO. SPECIES	S[1]	M	B	A	U
ROCHE BLAN.	Double Harvest	10.88	*Catalpa longissima*	orchard	**56**	*	*		*	*
		10.88	*Colubrina arborescens*	orchard	**27**		*		*	*
		10.89	*Simarouba glauca*	orchard	**20**	*	*		*	*
		10.89	*Simarouba berteroana*	orchard	**4**	*	*		*	*
		3.89	*Leucaena* K varieties	provenance	***4***	*	*	*	*	
		3.89	*Senna siamea*	provenance	***10***	*	*	*	*	*
		9.90	*Swietenia* hybrid	orchard	**3**			*	*	*
		7.91	*Azadirachta indica*	provenance	*14*	*	*	*	*	*
KENSCOFF	Jane Wynne	5.89	*Pinus* spp.	provenance	***28***		*	*	*	*
		4.91	*Grevillea robusta*	orchard	**23 (*3*)**		*	*	*	*
		9.90	*Calliandra calothyrsus*	provenance	*2*		*	*	*	*

[1] **An asterisk is assigned for each factor contributing to improved seed production:** **S**ecurity of the land in terms of long-term tree tenure**, M**otivational level of landowner and caretaker(s) to make necessary investments and take initiative to improve seed production**, B**iological match of species with site conditions that promote vigor and seed production, **A**ccessibility of site to market and technical assistance**, U**niqueness of trial in terms of species' genetic base in Haiti.

EXAMPLE OF A SUMMARY STATISTICAL TABLE FOR A *CORDIA ALLIODORA* PROVENANCE TRIAL AT 5 YEARS.

SIXTY MONTH SURVIVAL, DIAMETER AND HEIGHT MEASUREMENTS

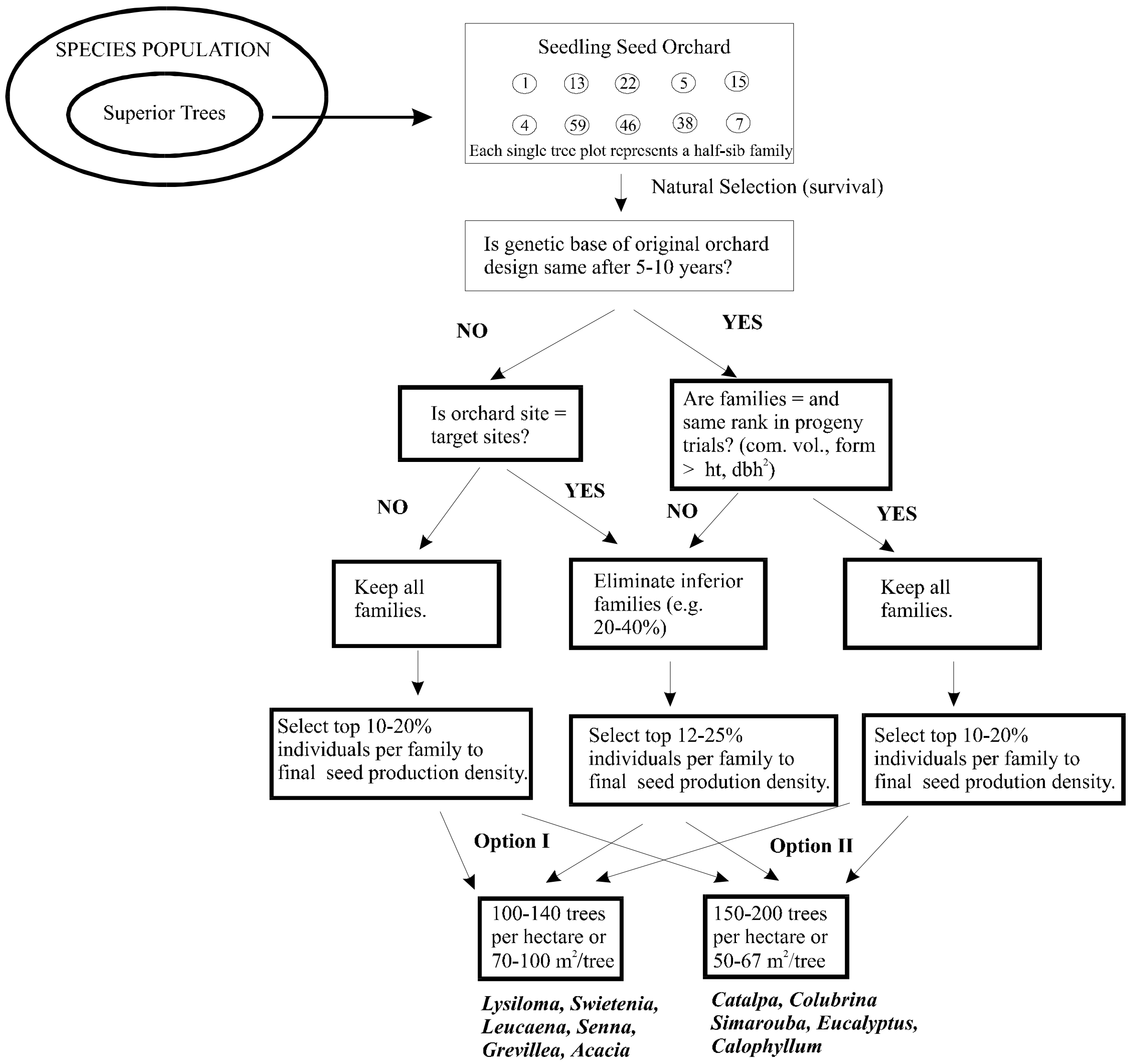
SITE: Bérault
#REPS: 3
SPECIES: *Cordia alliodora*
TREES PER REP: 18
DATE MEASURED: 05-94
 # BORDER ROWS: 1
MEASURED BY: L. VERRET / Y. ELIE
FILENAME: BECOAL60.MN

PROV. ID NO.	PLANTED (N)	LIVING (N)	SURVIVAL (%)	TOTAL MEAN HEIGHT (m)	NON-DAMAGED (N)	ND MEAN HEIGHT (m)	ND MEAN DBH (cm)	ND MEAN BASAL DIAM. (cm)	HUMAN DAMAGE (%)
B7488	**54**	**50**	**92.6**	**10.5**	**43**	**10.5**	**10.3**	**13.4**	**13.0**
4140	**54**	**34**	**63.0**	**10.0**	**27**	**10.1**	**10.8**	**14.3**	**13.0**
4107	**54**	**35**	**64.8**	**7.9**	**34**	**7.9**	**8.1**	**11.0**	**1.9**
1877	**54**	**35**	**64.8**	**7.9**	**33**	**8.0**	**10.4**	**14.4**	**3.7**
4108	**54**	**26**	**48.1**	**7.7**	**21**	**8.0**	**9.7**	**13.3**	**9.3**
SITE	**270**	**180**	**66.9**	**9.0**	**158**	**9.0**	**9.9**	**13.2**	**8.2**

FLOW CHART FOR SEED ORCHARDS

UPGRADING SEEDLING SEED ORCHARD

***Catalpa longissima, Simarouba glauca, Lysiloma sabicu, Colubrina arborescens, Swietenia* sp.**



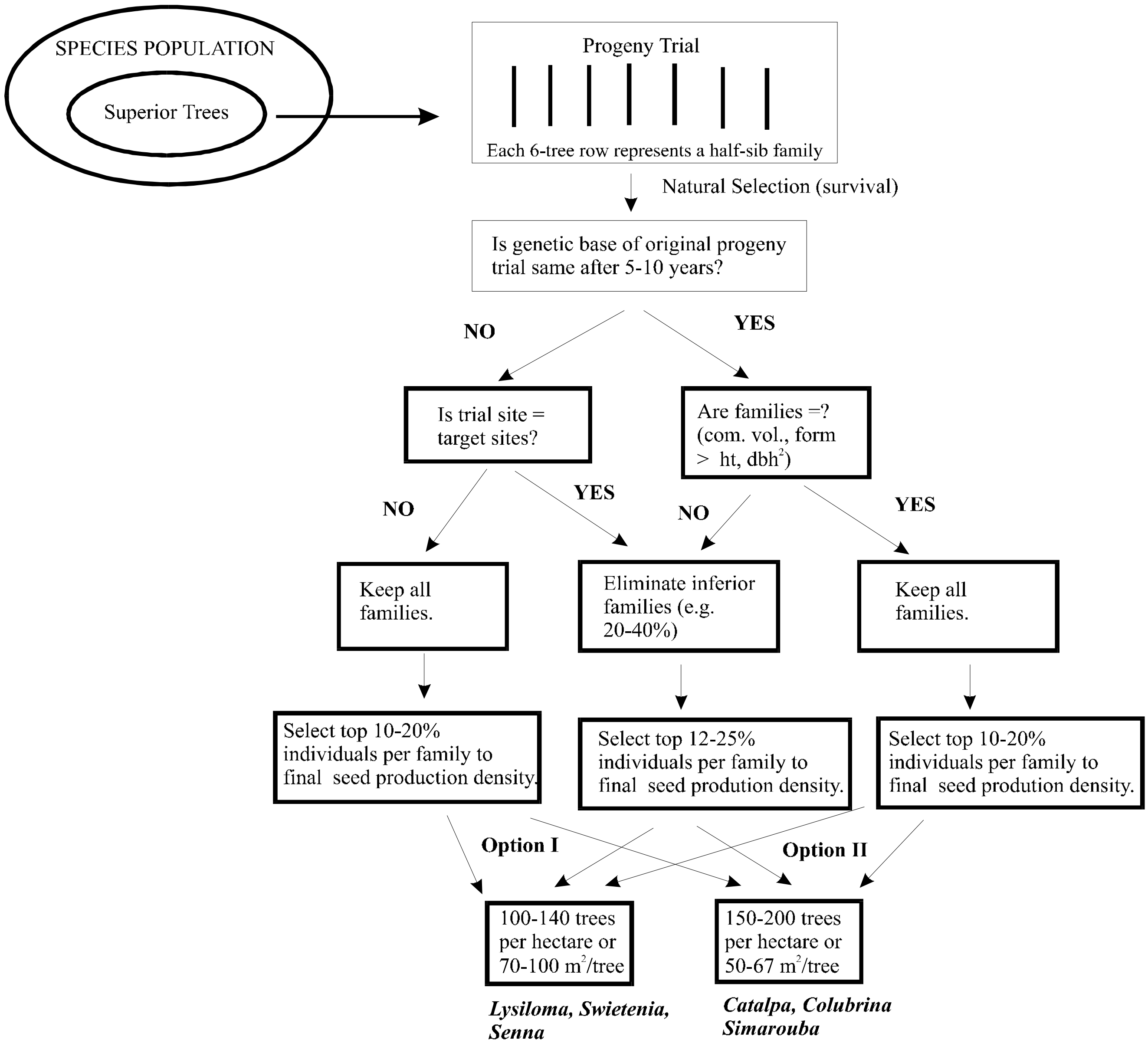
ATTENTION!!!

1) Individual selection should maximize liklihood of outcrossing with other superior families to avoid inbreeding..
2) Clones of superior families and individuals should be planted in 2nd generation orchards under systematic or randomized design to yield greater genetic gains.
3) There are several orchards that have mixed species (*Simarouba glauca & S. berteroana; Swietenia mahagoni & S. mcacrophylla; Leucaena diversifolia & L. leucocephala glabrata*) that were designed to produce hybrid seed. If so, then either select out one of the species for pure seed, retain both species for hybrid seed or determine if species are being cross-pollinated and the variability of progeny from these orchards.

FLOW CHART FOR PROGENY TRIALS

PROGENY TRIAL CONVERSION TO SEED ORCHARD

***Catalpa longissima, Simarouba glauca, Lysiloma sabicu, Colubrina arborescens, Swietenia* sp.**

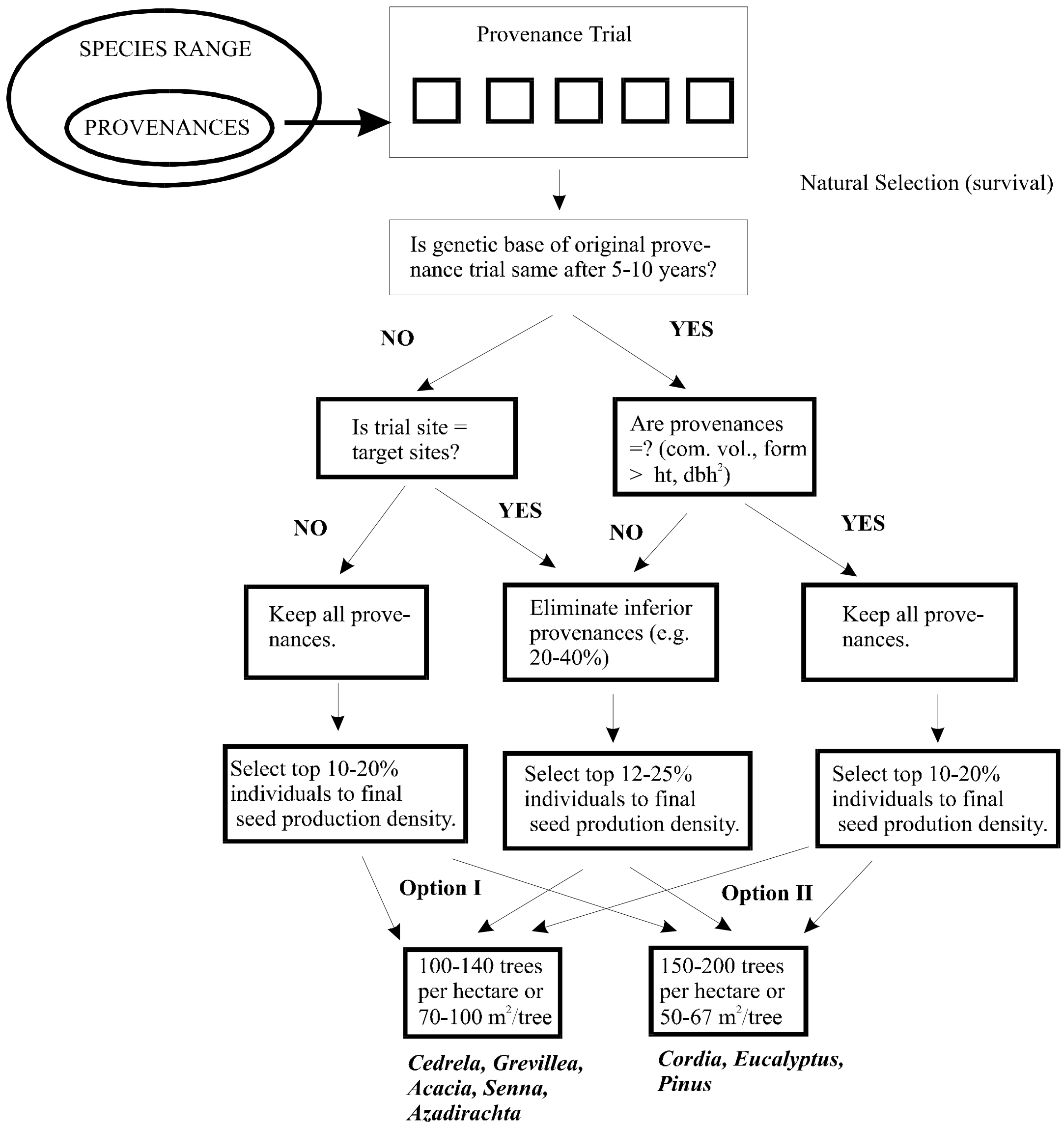


ATTENTION!!!

1) Individual selection should maximize liklihood of outcrossing with other superior families to avoid inbreeding..
2) Clones of superior families and individuals should be planted in 2nd generation orchards under systematic or randomized design to yield greater genetic gains.

FLOW CHART FOR PROVENANCE TRIALS
PROVENANCE TRIAL CONVERSION TO SEED PRODUCTION AREA

Cedrela odorata, Grevillea robusta, Acacia auriculiformis, Senna siamea, Cordia alliodora, Azadirachta indica



ATTENTION!!!

1) Widely differing provenances of certain genera and species (*Cedrela, Swietenia, Pinus, Eucalyptus*) should not be used for seed production if hybridization is not desired. Though hybrid seed is more vigorous, it is more variable and may lead to unpredictable results..
2) Clones of superior provenances should be planted in isolation to form pure stands for seed production. Seed should be imported from known provenance sources rather than collected as seed from provenance trial due to possible contamination with closely related species or provenance.

Example of SAS output for ANOVA and Waller-Duncan means comparison test. Note that the correct denominator to determine the F-value is the interaction term (REP*FAM) and not the residual.

The SAS System 15:44 Monday, April 21, 1999

General Linear Models Procedure
Class Level Information

Class	Levels	Values
REP	9	1 2 3 4 5 6 7 8 9
FAM	13	103 104 105 110 111 117 118 122 123 124 125 159 169

Number of observations in data set = 689

NOTE: Due to missing values, only 615 observations can be used in this analysis.

General Linear Models Procedure

Dependent Variable: MV

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	114	3204.92989043	28.11342009	2.72	0.0001
Error	500	5171.33093335	10.34266187		
Corrected Total	614	8376.26082378			

R-Square	C.V.	Root MSE	MV Mean
0.382621	78.49465	3.21600091	4.09709578

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	8	366.72147545	45.84018443	4.43	0.0001
FAM	12	1083.79385881	90.31615490	8.73	0.0001
REP*FAM	94	1754.41455617	18.66398464	1.80	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	8	382.17190018	47.77148752	4.62	0.0001
FAM	12	1070.38136409	89.19844701	8.62	0.0001
REP*FAM	94	1754.41455617	18.66398464	1.80	0.0001

Tests of Hypotheses using the Type III MS for REP*FAM as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FAM	12	1070.38136409	89.19844701	4.78	0.0001

Waller-Duncan K-ratio T test for variable: Commercial Volume

NOTE: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Kratio= 100 df= 94 MSE= 18.66398 F= 4.779175
Critical Value of T= 1.98502
Minimum Significant Difference= 1.7646
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 47.23323

Means with the same letter are not significantly different.

Waller Grouping			Mean	N	FAM
	A		6.7743	45	104
	A				
	A		6.4836	47	117
	A				
B	A		5.4120	50	105
B					
B	C		4.5620	45	123
B	C				
B	C	D	4.1427	50	111
B	C	D			
B	C	D	4.0329	51	122
B	C	D			
B	C	D	3.9641	47	103
B	C	D			
B	C	D	3.8886	47	118
	C	D			
	C	D	3.2045	47	110
	C	D			
	C	D	2.9390	45	124
	C	D			
	C	D	2.9242	47	125
		D			
		D	2.5132	46	159
		D			
		D	2.4261	48	169